The Properties and Genesis of Four Middle Altitude Dystrandept Volcanic Ash Soils from Mauna Kea, Hawaii[1]

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HAWAII is one of the volcanic areas of the world. Volcanic ash is widespread throughout the area, and many soils contain ash as part of their parent material. The soils derived from volcanic ash contain predominantly amorphous mineral colloids that have high chemical activity. The Hydrol Humic Latosols on which sugarcane is grown have received much study, but the volcanic ash soils in the higher elevations have not. This study provides information about these soils located at higher elevations.

REVIEW OF LITERATURE

In the new U. S. Comprehensive Soil Classification system (Soil Survey Staff, 1967), Andepts are defined as "Inceptisols that (1) have one or both of: (a) a bulk density [at field capacity] of the fine earth fraction of the soil of less than 0.85 g per cc in the epipedon or the cambic horizon, or both, and the exchange complex is dominated by amorphous materials; [or] (b) more than 60 per cent of vitric volcanic ash, cinders, or other . . . fractions; (2) are not saturated with water at any period or lack the characteristics associated with wetness defined for Aquepts; [and] (3) lack a plaggen epipedon." Dystrandept, one of the great soil groups of Andepts, has an umbric or ochric epipedon with fine to medium texture and 15-bar water retention greater than 20 per cent based on the average of the whole soil.

In Hawaii, mantles of volcanic ash are found overlying many of the lava flows. Swindale and Sherman (1964) divided this volcanic ash into three types according to composition and mode of occurrence: (1) andesitic ash, (2) phreatic basaltic ash, and (3) basic and ultrabasic ash. The rocks on the northern and northeastern parts of the island of Hawaii are covered with a mantle of andesitic ash of varying thickness. Houng (1964) examined the sand fractions of a number of soils derived from this ash and found oligoclase and andesine feldspars, olivine, enstatite, a few augites, and the accessory minerals, apatite and magnetite. He also found glass shards which were brown to greenish-brown.

Cline (1955) found that most of the soils formed from volcanic ash have a dark-colored A_1 horizon, are relatively high in organic matter, and grade to a lighter-colored B horizon. According to Swindale and Sherman (1964), these soils have either an AC or an A(B)C profile with friable A horizon. Flach (1964) observed that the most outstanding characteristic of the Andepts is their smeariness, that is, their tendency to appear moist when undisturbed, and wet when crushed. In the field, these soils tend to have an intermediate apparent texture but, when analyzed in the laboratory, they are found to be much finer.

The sand fraction of these soils usually contains volcanic glass and rock-forming minerals such as feldspars, pyroxenes, hornblende, and magnetite, with very little or no mica (Swindale, 1964; Birrell, 1964). In most of these soils, the secondary minerals are predominantly allophane or other amorphous minerals. In Hawaii, Kelly and Page (1943) found considerable amounts of amorphous material in certain soils. Tamura et al. (1953, 1955), studying the mineral content of Low Humic, Hydrol Humic, Humic Ferruginous latosols, found appreciable amounts of allophane in some of these soils.

Several workers have studied the weathering

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of the minerals present in these Ando-like soils. According to Fieldes and Swindale (1954), feldspars as well as volcanic glass are converted to amorphous hydrous oxides which alter first to allophane and then to kaolin minerals. Tamura and Jackson (1953) proposed a system of structural and energy relationships of iron and aluminum oxides, hydroxides, and silicates, showing a sequence of conversion of ionic elements to crystalline minerals through an intermediate stage involving amorphous mineral colloids. In studying the differential weathering of volcanic ash and pumice, Aomine and Wada (1962) proposed a sequence of relative stability of the primary minerals to weathering, the stability increasing in the following order: volcanic glass < feldspar < hypersthene-augite < magnetite. They also came to the conclusion that volcanic glass and feldspars weather to allophane, which in turn weathers to hydrated halloysite.

Soils derived from volcanic ash have peculiar properties due to the high reactivity of the amorphous fraction which possesses a high specific surface charge. Studies on Japanese soils (Kawamura, 1952, summarized in "Volcanic Ash Soils of Japan," 1964) indicate that these soils could have a high content of organic matter (up to 30 per cent) and very high carbon-nitrogen ratio (up to about 24), particularly in the surface soils. Cation exchange capacities of these soils are also found to be high. Fieldes, Swindale, and Richardson (1952) found that the cation exchange capacity of some soils of the Lower Cook Islands group is due mainly to amorphous colloidal hydrous oxides. High values for the cation exchange capacity of allophane were found by several workers (White, 1953; Aomine and Yoshinaga, 1955; Birrell and Fieldes, 1952). The pH values of volcanic ash soils are usually above 5.0. It is unusual to find lower pH values because of the strong buffering capacity of polymerized alumina gels (Swindale, 1964; Birrell, 1964). Birrell (1964) mentioned that the base saturation of allophane could be very low, even though the pH values indicate only weak to moderate acidity. Swindale (1964) pointed out that the estimation of base saturation of allophanic soils is unreliable since the amorphous mineral colloids have pH dependent charge, and the base saturation measured in the laboratory at pH 7 may be much lower than the actual condition at a lower pH.

Birrell (1964) mentioned that these soils have a very high moisture content throughout the profile and a very low bulk density value. He also said that the particle size distribution of soils derived from volcanic ash has not much meaning due to the presence of (1) amorphous colloids which have a high iso-electric point, and (2) hydrous oxides which induce mutual coprecipitation.

THE SOILS

Four soils, originally classified as Latosolic Brown Forest (Cline, 1955), were collected on the northern slopes of Mauna Kea from an elevation of 3,400 to 6,900 feet. The approximate locations of the sample sites and the extent of ash in this region are shown in Figure 1, prepared from information presented in a geological map published by Stearns and Macdonald (1946). Judging from their information, the Hanaipoe soil is derived from the lavas of the Laupahoehoe Volcanic Series, and the other three soils are derived from andesitic ash overlying these rocks (but see page 168).

Some of the genetic factors of the soils are shown in Table 1. The median annual rainfall at each sample site was determined from the rainfall gauges located near the sample sites, while the mean annual temperature was deter-

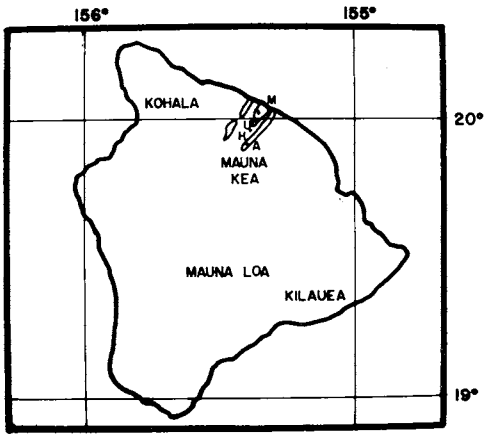

FIG. 1. Map of the island of Hawaii, showing the location and extent of the ash. *A*, Apakuie; *H*, Hanaipoe; *U*, Umikoa; *M*, Maile.

TABLE 1

SOME GENETIC FACTORS OF THE SOILS

SOIL	ELEVATION (feet)	MEAN ANNUAL RAINFALL (inches)	SOIL TEMPERATURE AT 50 INCHES (°F)	VEGETATION
Apakuie	6,900	24	55	Mamani, grass cover
Hanaipoe	5,100	42	62	Pasture
Umikoa	4,350	55	65	Pasture
Maile	3,400	72	65	Ohia, grass cover

mined from soil temperature taken at a depth of 50 inches. The sample sites are generally cloudy and foggy throughout the year. All of these soils are well drained and have similar slopes.

METHODS

The freshly collected samples were crushed gently and passed through a 2-mm sieve. The sieved sample was then thoroughly mixed and subsampled. One subsample was air-dried and ground further to pass through a 100-mesh sieve, thoroughly mixed, and stored for carbon, nitrogen, free iron oxide, and differential thermal analyses. Another subsample was kept moist in plastic bags and was used to determine pH, cation exchange capacity, and particle size distribution. Moist sample was analyzed because some of the properties of volcanic ash soils tend to change when they are dried.

Particle size distribution was carried out according to Jackson's (1956) method. The sand and silt fractions of selected samples were examined by means of a petrographic microscope. In addition to these fractions, the clay fraction was analyzed by means of a Norelco Philip X-ray diffractometer using Cu K_α radiation and a Ni filter. Differential thermal analyses (D.T.A.) were carried out on all samples. The 100-mesh air-dried soil was kept for three days in a vacuum desiccator saturated with $Mg(NO_3)_2$ to keep the relative humidity at about 57 per cent. A 0.10-gram sample was mixed thoroughly with 0.09 gram of calcined alumina and then analyzed by means of a Stone D.T.A. apparatus at the rate of 10°C per minute from 25 to 1050°C. Selected clays were also analyzed. Nitrogen gas was used to suppress the oxidation of organic matter. To accommodate the first endothermic peak (approximately 150°C) on the recording paper, the sensitivity of the recorder was reduced by one half in the temperature range, ambient to 210°C.

Soil pH was determined in H_2O (1:5) by means of a Beckman pH meter. Organic matter was determined by the Walkley-Black (1934) method using a recovery factor of 77 per cent. Free iron oxides were determined by Kilmer's method (1960). Total nitrogen was determined by Kjeldahl's method. In the determination of cation exchange capacity and exchangeable cations, neutral normal ammonium acetate solution served as the replacing agent. The 15-bar water was determined by using the pressure membrane apparatus.

RESULTS AND DISCUSSION

General

The chemical, physical, and mineralogical data of the four soils are presented in Table 2. The results of the X-ray diffraction and petrographic analyses of the sand and silt fractions showed the presence of volcanic glass, plant opal, plagioclase feldspars, magnetite, quartz, and small amounts of olivine and pyroxenes. X-ray diffraction and differential thermal analyses of the clay fractions revealed the presence of allophane, gibbsite, and small amounts of layer silicates. The presence of allophane is indicated by the background scatter in X-ray diffraction patterns (Fig. 2) and by the first endothermic peak at 125 to 150°C of the differential thermal analyses (Fig. 3). Since the layer silicates are either absent or present in very small amounts, the endothermic peaks are attributed to the water of hydration of allophane. Similar

TABLE 2

SUMMARY OF THE PROPERTIES OF THE SOILS

SOIL	MINERALS*	pH (1:5, H_2O)	CARBON (%)	CARBON NITROGEN RATIO	EXCHANGEABLE CATIONS (meq per 100 g) TOTAL	Ca	Mg	K	Na	BASE SATURATION	FREE IRON OXIDES†	SAND (%)	SILT (%)	CLAY (%)	15-BAR WATER (%)
Apakuie															
A_1	P, V, Mg, O, A	5.8	16.50	15	40.8	19.4	3.5	0.9	0.1	59	10.4	33.0	45.3	21.8	22.7
B_2	P, V, Mg, O, A	6.5	6.10	11	41.9	10.9	1.6	0.6	0.1	31	13.1	21.9	40.2	37.9	27.0
IIAb	P, V, Mg, O, A	6.7	5.52	13	38.5	10.7	1.4	0.4	0.1	33	10.4	16.2	46.7	37.1	22.3
II_{C1}	P, V, Mg, O, A	6.8	3.30	14	29.6	8.5	1.4	0.5	0.1	35	9.0	58.7	22.9	18.4	23.3
II_{C2}	P, V, Mg, O, A	7.0	1.98	15	15.0	3.8	0.6	0.6	0.1	34	6.7	69.8	16.4	13.8	25.9
Hanaipoe															
A_{p1}	P, Mg, V, O, A	5.1	21.3	14	56.5	10.4	7.3	0.5	0.1	32	15.7	13.2	54.9	31.9	48.8
A_{p2}	P, Mg, V, O, A	6.0	15.1	15	85.9	20.0	4.5	0.3	0.1	29	17.3	4.2	27.6	68.2	91.5
B_{21}	P, Mg, V, O, A	6.2	11.6	16	85.8	13.6	4.1	0.2	0.2	21	16.0	3.7	32.7	63.9	109.9
B_{22}	P, Mg, V, O, A	6.0	9.4	14	88.0	5.4	1.8	0.0	0.2	8	18.1	4.6	31.9	63.5	113.3
B_{23}	P, Mg, V, O, A	6.0	8.7	15	81.4	2.8	1.8	0.1	0.2	6	13.8	3.6	31.6	64.8	119.6
C	P, Mg, V, O, A	6.5	4.6	19	52.6	1.2	0.8	0.1	0.1	4	7.7	41.2	27.8	31.1	52.3
B_{24b}	P, Mg, V, O, A	6.2	6.2	13	81.8	2.0	0.2	0.0	0.1	3	14.2	5.4	37.7	56.5	103.9
Umikoa															
Ap	P, Mg, O, Q, G, K, M, Vr, A	5.9	14.0	13	72.1	6.2	2.0	0.4	0.1	12	21.1	9.3	23.9	66.8	61.7
B_{21}	P, Mg, O, Q, I, G, K, M, Vr, A	6.0	11.3	18	94.9	7.5	1.6	0.1	0.1	10	15.8	5.7	19.5	74.8	160.2
C	P, Mg, O, I, Q, G, A	6.0	9.7	18	94.7	5.0	1.1	0.1	0.0	7	12.1	4.3	12.6	83.1	164.2
B_{22b}	P, Mg, O, Q, I, G, K, M, Vr, A	5.9	9.2	20	93.0	3.1	0.3	0.1	0.1	4	12.8	2.9	14.4	82.7	184.6
B_{23b}	P, Mg, O, Q, I, G, K, M, Vr, A	5.8	9.2	17	97.0	2.0	0.5	0.2	0.3	3	17.2	5.1	15.5	79.4	202.3
B_{24b}	P, Mg, O, Q, I, G, K, M, Vr, A	5.7	6.0	13	79.1	1.2	1.0	0.2	0.1	3	12.0	5.2	31.0	63.8	171.6

TABLE 2 (*continued*)

SOIL	MINERALS*	pH (1:5, H_2O)	CARBON (%)	CARBON NITROGEN RATIO	EXCHANGEABLE CATIONS (meq per 100 g)					BASE SATURATION	FREE IRON OXIDES†	SAND (%)	SILT (%)	CLAY (%)	15-BAR WATER (%)
					TOTAL	Ca	Mg	K	Na						
Maile															
A_{11}, A_{12}	Mg, I, O, Q, G, K, M, Vr, A	4.7	11.05	17	37.1	2.0	0.4	0.2	0.1	7	37.5	21.9	23.6	54.5	40.5
A_{13}	Mg, I, O, Q, G, K, M, Vr, A	5.3	11.51	17	66.6	0.5	0.2	0.1	0.1	1	14.5	4.6	18.7	76.7	155.2
IIB_{21}, $IIIB_{22}$, IVB_{23}, VC	Mg, I, O, Q, G, K, M, Vr, A	5.5	9.56	17	40.9	0.4	0.2	0.1	0.1	2	14.9	4.9	17.2	77.8	164.0
VIB_{24}	Mg, I, O, Q, G, K, M, Vr, A	5.6	9.00	20	53.6	0.4	0.3	0.1	0.1	2	17.4	3.9	22.5	73.7	185.7
$VIIB_{25}$	Mg, I, O, Q, G, K, M, Vr, A	5.5	9.20	22	75.4	0.6	0.3	0.1	0.0	1	10.9	5.6	17.7	76.7	167.9
$VIIIB_{26}$	Mg, I, O, Q, G, K, M, Vr, A	5.9	5.08	24	37.5	0.5	0.2	0.1	0.1	2	8.9	7.3	42.0	50.7	114.3

† Expressed as grams per 100 grams of mineral soil.

* Explanation of symbols: P, plagioclase feldspar; Mg, magnetite; V, volcanic glass; O, olivine; I, ilmenite; Q, quartz; G, gibbsite; K, kaolin; Vr, vermiculite; M, mica; A, allophane.

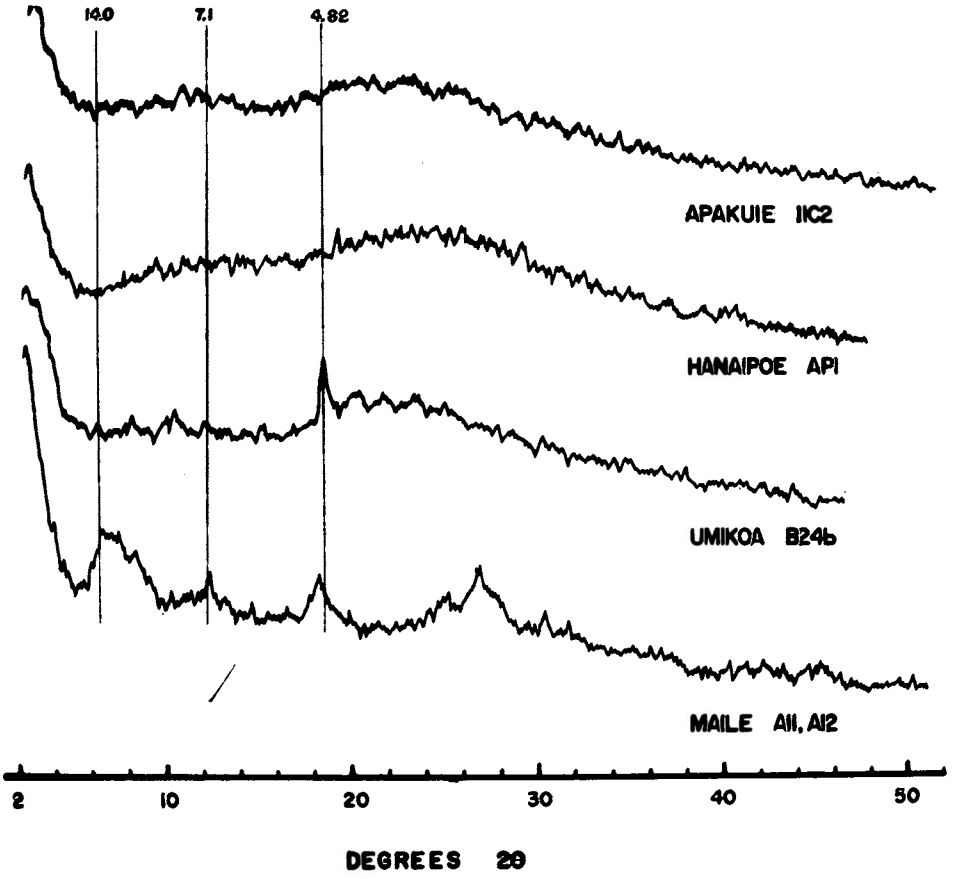

FIG. 2. X-ray diffraction patterns of selected fine clays (<0.2μ).

results were reported on allophane examined by Fieldes (1955) and Egawa (1964). Allophane in these soils must have been produced from the weathering of plagioclase feldspar or volcanic glass.

The presence of weak 14Å, 10Å, and 7Å X-ray diffraction peaks suggested the presence of some layer lattice type minerals. The results of differential cation saturation and glycol solvation of some of the clays (Fig. 4) indicated that the peaks are due to vermiculite, mica, and kaolin minerals, respectively. It was not possible to distinguish between kaolinite and halloysite from the weakly formed kaolin peaks. Kaolin in the soil may have formed from allophane on completion of undirectional bonding through alternate wetting and drying in an acid medium (Tamura and Jackson, 1953). The presence of mica and vermiculite may be due to the resilication of gibbsite, allophane, or kaolin. Vermiculite occurs in places of low base saturation and low pH (Fieldes and Swindale, 1954). The Maile and Umikoa soils provide similar conditions for the formation of this mineral. The 10Å micaceous mineral is probably formed by the accumulation in the interlayer of vermiculite of potassium from the vegetation.

Mineralogical analyses showed that all of the soils have large amounts of amorphous colloids in the clay fractions and pyroclastic material in the coarse fractions. The soils lack the characteristics associated with wetness as defined for Aquepts. These soils have dark-colored surface horizons containing large amounts of organic carbon and having base saturation less than 50 per cent (NH_4OAc; pH 7). These properties suggest that the soils should be classified in the suborder Andepts.

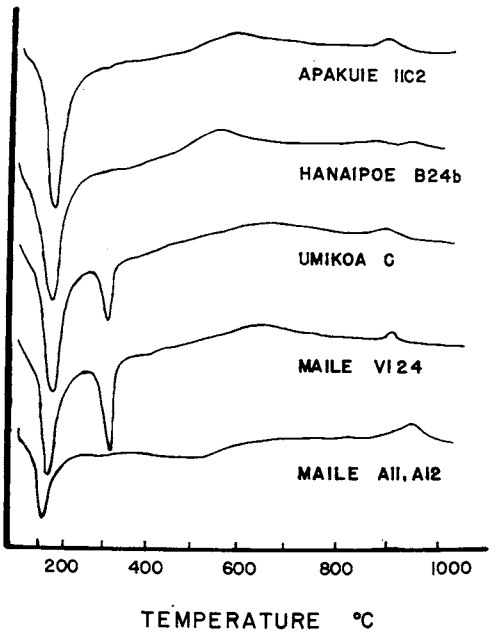

FIG. 3. Differential thermal analysis patterns of selected coarse clays (2μ–0.2μ).

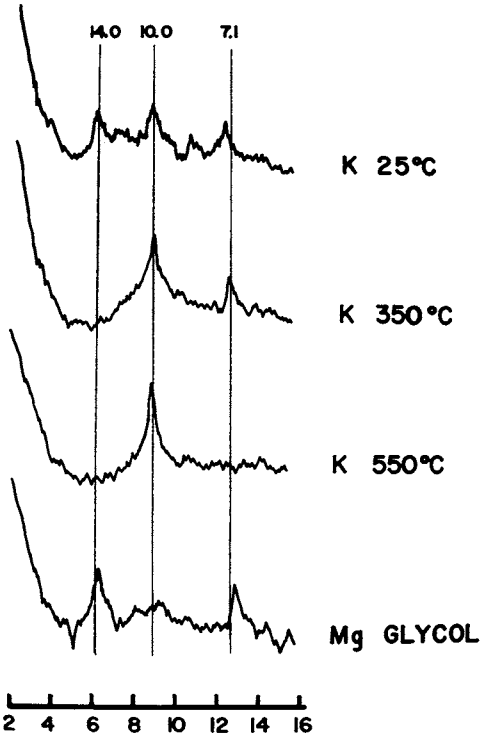

FIG. 4. X-ray diffraction patterns of the clay fractions of Maile (A11, A12) horizon after differential cation saturation and glycol solvation.

The soils have a mean annual soil temperature higher than 47°F, and hence do not belong to the Cryandepts. The absence of duripans and a mollic epipedon indicate that none of the soils belong to the Durandepts or Eutrandepts. The clays of these soils dry irreversibly but do not form gravel-sized aggregates, and therefore they are not Hydrandepts.

These soils have an umbric epipedon, textures of fine loamy, fine silty or finer, and 15-bar water greater than 20 per cent, hence they are classified as Dystrandepts.

Apakuie Soil

The Apakuie soil probably developed from the ash deposits from Puu Kihe cone. This soil is formed at high altitudes on Mauna Kea with a median annual rainfall of 24 inches and a soil temperature of 55°F (present climate).

The soil has large amounts of plagioclase feldspars, magnetite, and volcanic glass, and small amounts of olivine and pyroxenes in the sand and silt fractions. The clay fraction consists mainly of allophane. This soil has the highest amount of allophane in the clay fraction, indicating that the allophane formed is not decomposed to other minerals. All these facts indicate that the soil is not highly weathered due to the mild climate of this area.

An abrupt wavy boundary between the B_2 and IIAb horizons indicates that there is a lithologic discontinuity at this level. The variations in pH, organic carbon, cation exchange capacity, and exchangeable Ca down the profile indicates that either the soil is formed on one ash deposit without any buried horizons, or sufficient time was not available for the buried horizons to develop, if there were any.

As is seen from the particle size distribution, this soil is slightly medium to coarse in texture, mainly in the last two horizons. Although relatively small amounts of the clay fraction were present, the cation exchange capacity and the 15-bar water are not as low as expected because the clay is predominantly allophane. Cation exchange capacity decreases with depth due to

the decrease in the amount of clay. Base saturation is high with values ranging from 32 to 58 per cent. The high amounts of exchangeable Ca are probably due to the presence of high amounts of plagioclase feldspar which continues to weather. The low amount of rainfall in this area did not leach all the bases.

The organic matter content is very high in the A_1 horizon and decreases down the profile. The pH values indicate a slightly acid to neutral reaction in these soils. The increase of pH down the profile may be due to the decreasing amount of organic matter. The decrease in free iron oxides down the profile is expected from the decrease in acidity and in degree of weathering. The Apakuie soil has all the properties of a Typic Dystrandept except that the umbric epipedon is less than 10 inches thick and, therefore, the Apakuie soil is classified as an Entic Dystrandept.

Hanaipoe Soil

The nature of the parent material from which the Hanaipoe soil is derived is not known. According to the map described by Stearns and Macdonald (1946), the location of the Hanaipoe soil shows that it is formed on lava flows. However, the morphology of the soil and the large amount of allophane detected indicate that this soil is derived from volcanic ash probably of the same origin as the Apakuie soil.

The mineralogy of this soil is similar to that of the Apakuie soil. Dominant minerals present in the sand and silt fractions are plagioclase feldspar, volcanic glass, magnetite, and small amounts of olivine and pyroxenes. The clay fraction is composed mainly of allophane.

Particle size distribution indicates that there are one or more buried horizons. There is a definite, sharp change in the amount of sand in the C horizon. This may be due to differences in the physical nature of the ash from which this horizon is derived; the ash was probably denser, coarser, and more compact, and, therefore, more resistant to weathering than were the later deposits. Because the weathering in this C horizon is weak, the amounts of free iron, cation exchange capacity, and 15-bar water are also low. The C/N ratio of this C horizon is large compared with those of the adjacent horizons. This may be due to the high pH and the compact, sandy nature which produce anaerobic conditions for the decomposition of organic carbon. The large amount of sand and small amount of clay in the A_{p1} horizon may be due to irreversible drying of the allophanic clay. This irreversible drying is probably the reason for the low cation exchange capacity and 15-bar water of this horizon in comparison with those of the other horizons.

The pH values indicate that the soil is slightly acid in reaction. The organic carbon content is found to decrease down the profile. The largest amount of organic carbon in the whole sequence is found in the A_{p1} horizon of the Hanaipoe soil. The low pH of this horizon may be due to this high amount of organic carbon.

Profile development in this soil is confined to the formation of granular umbric epipedon. The Hanaipoe soil has all the properties of a Typic Dystrandept and is classified in this group.

Umikoa Soil

The Umikoa soil is probably developed from volcanic ash deposited from the summit cones of Mauna Kea (Frazer, 1960). This soil has a median annual rainfall of 55 inches and a mean soil temperature of 65°F.

Dominant minerals in the sand and silt fractions are magnetite, quartz, and small amounts of plagioclase feldspars, olivine, volcanic glass, and ilmenite. The clay fractions contain allophane and gibbsite as major constituents with very small amounts of layer silicates. The amount of quartz decreases from the surface down to the C horizon, then increases to the next horizon and decreases again. The pH increases down to the C horizon and then decreases gradually down the profile. Mineralogical analyses show that the C horizon is highly amorphous and has the least amount of layer silicates in comparison with the other horizons of this soil. All of these findings indicate that less soil formation has taken place in the C horizon than in the other horizons of the profile. This anomaly is probably due to the formation of surface horizons formed on parent material deposited on well-developed horizons buried below the C horizon. Comparatively higher base saturation of the first three surface horizons further supports this view.

The pH values indicate a slightly acid reaction in the soil and show insignificant differences

within the profile. Except for the A_p horizon, all of the other horizons have similar cation exchange capacities, 15-bar water, organic carbon, and pH_{H_2O}. These results show either that the soil materials within the profile are uniformly redistributed by the soil-forming processes or that weathering has brought the different materials to the same equilibrium end point.

The A_p horizon has different properties from those of the lower horizons probably because of irreversible drying of allophanic clay. This horizon is low in cation exchange capacity, per cent clay, and 15-bar water. Organic carbon and base saturation decrease uniformly in content down the profile. The Umikoa soil has all the properties of a Typic Dystrandept and is classified in this group.

Maile Soil

The Maile soil occurs at the lowest elevation in the sequence. It has a median annual rainfall of 72 inches and a mean soil temperature of 65°F. In the sequence under study, this soil showed the highest degree of weathering.

The main minerals present in the sand and silt fractions are magnetite and very small amounts of ilmenite, olivine, and volcanic glass. The clay fraction contains quartz, gibbsite, kaolin, mica, vermiculite, and allophane. The near absence of volcanic glass and feldspars indicates that this soil is strongly weathered. The small amount of allophane in the clay fraction of this soil in comparison with the other soils in the sequence indicates that some of the allophane has been converted to layer silicates or gibbsite. Quartz content is largest among the soils in this sequence. The amount of quartz decreases from the surface to the third horizon (IIB_{21}, $IIIB_{22}$, IVB_{23}, VC), then increases immediately to VIB_{24}, and decreases again finally in the horizons below. The increase indicates the presence of at least one buried horizon. Variations in the amounts of total exchangeable cations and per cent base saturation with depth follow a zigzag pattern suggesting the presence of buried horizons. It should be noted that the other properties, such as pH, per cent organic carbon, per cent free iron oxides, per cent clay, and per cent water held at 15-bar water, exhibit remarkably uniform values in all horizons. This uniformity indicates that, although lithologic discontinuities exist in this profile, the soil-forming processes have either redistributed the soil materials within the profile or brought the different materials to virtually the same equilibrium end point.

The surface horizon (A_{11}, A_{12}) shows extremely different properties from the other horizons. Per cent base saturation, per cent sand, and per cent free iron oxides in the surface horizon are very high compared with those in the lower horizons. The pH and per cent water held at 15-bar water are very much lower in the surface horizon than in the other horizons. The apparent weaker degree of weathering of the surface horizon which is exposed to a high temperature and high rainfall regime presents an interesting picture of the mutually opposing influences of various factors and processes of soil formation in an ash-derived soil. The high temperature and high rainfall at the surface must have caused an alternate wet and dry condition which favors irreversible drying of the allophanic clay. The irreversible drying of the clay probably produced the larger amount of sand, lower 15-bar water, and lower cation exchange capacity values. The granular structure, low moisture content, and alternate wet and dry conditions are probably the cause of the high free iron oxide content of this horizon. Low gibbsite and high vermiculite contents are expected from the low pH of this horizon.

Data on these properties indicate that there is little profile development except for darkening and the formation of granular structure in the A horizon.

The Maile soil has all the properties of a Typic Dystrandept except that it is wet throughout the year and shows more irreversible drying. It is classified as a Hydric Dystrandept.

SUMMARY

The four soils collected from the middle altitudes of the northern slopes of Mauna Kea, Hawaii, contained volcanic glass and plagioclase feldspars in the silt and sand fractions of some horizons, together with magnetite, plant opal, and small amounts of olivine and pyroxenes. The clay fractions of all the soils contained allophane. The Umikoa and Maile soils, the two wetter members, contained gibbsite and small

amounts of kaolin, mica, and vermiculite. The four soils, arranged in order of decreasing amounts of allophane in the clay fraction, are: Apakuie > Hanaipoe > Umikoa > Maile.

Profile differentiation was confined only to the formation of the dark granular epipedons, except in the Maile soils where additional differences occurred in the surface horizon.

The Apakuie soil is moderately weathered, neutral to slightly acid, moderate in amounts of base saturation, and medium in cation exchange capacity. The Hanaipoe soil is moderately to strongly weathered, slightly acid in reaction, and has low base saturation, high cation exchange capacity, and very high organic matter. The Umikoa soil is strongly weathered, is slightly acid in reaction, and has very low base saturation, high cation exchange capacity, and high organic matter. The Maile soil is very strongly weathered, is acid in reaction, and has very low base saturation, high cation exchange capacity, and high organic matter.

The Apakuie soil, the driest and least weathered, is classified as an Entic Dystrandept; Hanaipoe and Umikoa soils are Typic Dystrandepts; and the Maile soil, the wettest and most weathered, is a Hydric Dystrandept.

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